Portable Electron-Beam Free-Form Fabrication System

The electron beam in this system will be of relatively low voltage.

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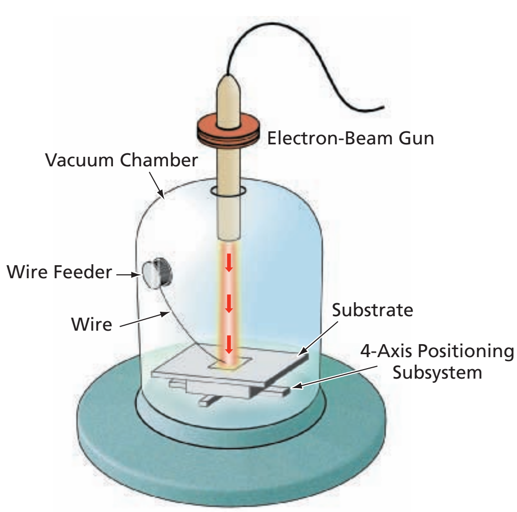
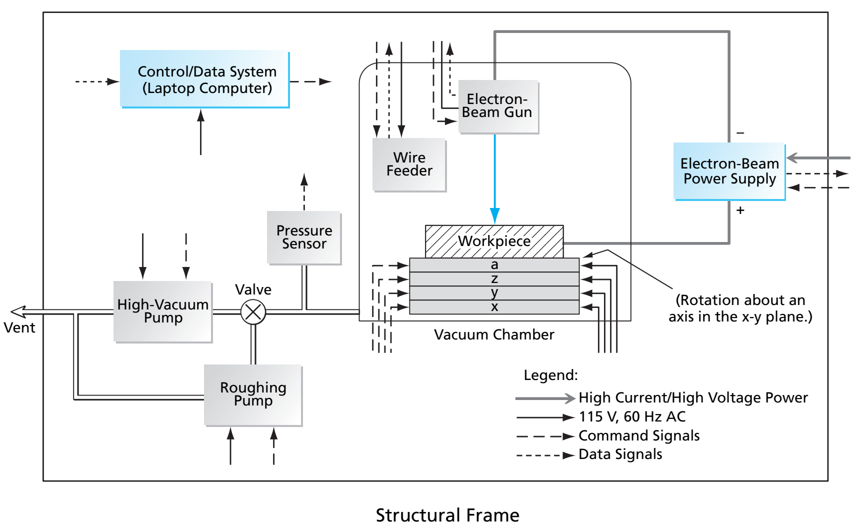
A portable electron-beam free-form fabrication (EB F^3) system, now undergoing development, is intended to afford a capability for manufacturing metal parts in nearly net sizes and shapes. Although the development effort is oriented toward the eventual use of systems like this one to supply spare metal parts aboard spacecraft in flight, the basic system design could also be adapted to terrestrial applications in which there are requirements to supply spare parts on demand at locations remote from warehouses and conventional manufacturing facilities.



ARTIST'S CONCEPTION OF VACUUM CHAMBER AND EQUIPMENT WITHIN



SCHEMATIC DIAGRAM OF SYSTEM

A **Metal Workpiece Will Be Formed** by using an electron beam to melt feed wire over a substrate that will be moved by a four-axis positioning subsystem.

Prior systems that have been considered for satisfying the same requirements (including prior free-form fabrication systems) are not easily portable because of their bulk and massive size. The mechanical properties of the components that such systems produce are often inferior to the mechanical properties of the corresponding original, conventionally fabricated components. In addition, the prior systems are not efficient in the utilization of energy and of feedstock. In contrast, the present developmental system is designed to be sufficiently compact and lightweight to be easily portable, to utilize both energy and material more efficiently, and to produce components that have mechanical properties approximating those of the corresponding original components.

The developmental EB F^3 system will include a vacuum chamber and associated vacuum pumps, an electron-beam gun and an associated power supply, a multiaxis positioning subsystem, a precise wire feeder, and an instrumentation system for monitoring and control. The electron-beam gun, positioning subsystem, and wire feeder will be located inside the vacuum chamber (see figure). The electron-beam gun and the wire feeder will be mounted in fixed positions inside the domed upper portion of the vacuum chamber. The positioning subsystem and ports for the vacuum pumps will be located on a base that could be dropped down to provide full access to the interior of the chamber when not under vacuum.

During operation, wire will be fed to a fixed location, entering the melted pool created by the electron beam. Heated by the electron beam, the wire will melt and fuse to either the substrate or with the previously deposited metal wire fused on top of the positioning table. Based on a computer aided design (CAD) model and controlled by a computer, the positioning subsystem will move the substrate so that the metal deposited from the wire will accumulate to form a component of the desired size and shape.

Whereas conventional electron-beam welding systems generally utilize electron-accelerating potentials of the order of 60 kV, the proposed system will utilize a potential between 8 and 15 kV. Consequently, the shielding needed to protect personnel and equipment against x rays generated by impingement of the electrons on the workpiece can be considerably less massive. The electron beam will deliver a maximum power between 3 and 5 kW and be focused to heat a small spot. Because a considerably higher fraction of an electron beam's energy is converted into heat (relative to a laser beam, for example) in a small spot on the workpiece, the use of the electron beam will contribute to the energy efficiency of the system. The use of the precise wire feeder will enable efficient utilization of feedstock. The operational parameters will be selected to ensure the proper feeding, melting, and consolidation of the feedstock to yield a deposit that will be nearly 100 percent dense (that is, will contain little or no porosity) and will have a very fine grain structure, as needed to ensure superior mechanical properties.

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